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Bedform and Flow Relationships, Little Missouri River Near Medora, North Dakota

Richard Halle

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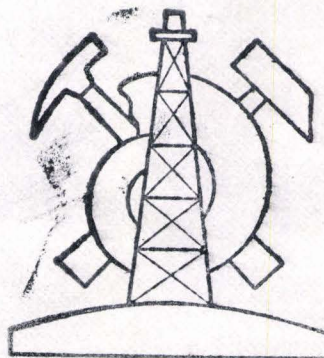
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BEDFORM AND FLOW RELATIONSHIPS,
LITTLE MISSOURI RIVER
NEAR MEDORA, NORTH DAKOTA

A senior thesis prepared by Richard E. Halle
for the Geology Department of the University
of North Dakota in partial fulfillment of the
requirements for the Degree of Bachelor of
Science in Geology.

Frank R. Karner, thesis advisor.



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This thesis submitted by Richard E. Halle in partial fulfillment of the requirements for the Degree of Bachelor of Science in Geology from the University of North Dakota is hereby approved by the Faculty Advisor under whom the work has been done.

COTTON FIBER CONTENT

Frank Kamez
(Advisor)

ABSTRACT

Data concerning flow conditions over known bedforms in the Little Missouri River were used to seek relationships between the two. The flow parameters that were measured included: current velocity, depth, water temperature, and suspended-load concentration. A bedload sample was also taken at each bedform. The median grain size of the sand fraction of the bedload sample was measured with a recording settling tube. Three relationships (velocity: depth, Reynolds number: Froude number, Reynolds number: median grain size of sand) were moderately successful in separating ripples from dunes but failed to isolate plane bed. The use of velocity near the bed to calculate the Froude number results in a relatively small Froude number. The choice of formulas to calculate the Froude number also has a large effect on its size.

In future studies the slope of the water surface should be measured and viscosity should be determined with a viscosimeter.

INTRODUCTION

Crossbeds in sedimentary rocks have long been used to infer paleoflow directions, current velocities, and water depths. Several studies of the bedforms that produce these crossbeds have been made in flumes (Simons, Richardson, Albertson, 1961). The studies point out some relationships between flow and bedforms, but they are the result of special conditions: the water in a flume is restricted between smooth vertical walls; depths are usually shallow; bed configuration is uniform across the bottom; and factors affecting water viscosity are often held constant (Colby & Scott, 1965). Shouldn't data gathered from natural streams be more realistic? This project was undertaken in the Little Missouri River during the summer of 1971. It was supervised by Dr. Arthur Jacob and supported by National Science Foundation Undergraduate Research Participation grant GY-8753.

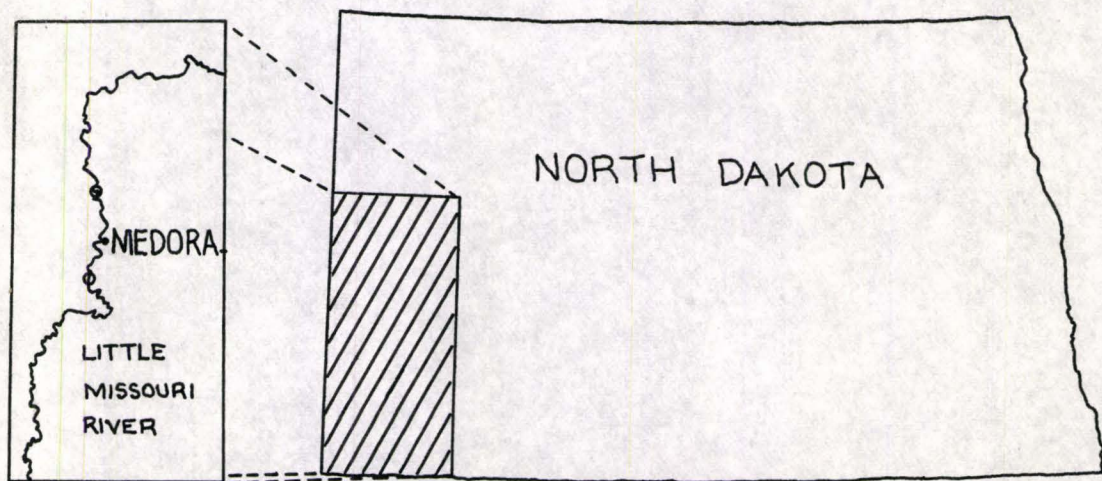


FIG. 1.--Map showing study areas as circles on Little Missouri River.

METHODS

Field Methods

Samples were collected wherever bedforms were found in the study areas. The study areas, marked on Figure 1, are two approximately one mile long stretches of the river chosen for easy accessibility.

The important flow parameters (Simons, Richardson, and Nordin, 1965) which were measured include: current velocity, depth, water temperature, and suspended load. The water surface slope should have been measured but wasn't. A sample of the bedload was taken and the bedform recorded at each point. All measurements were made while wading in the river. Equipment used included: velocity meter; thermometer; water sampler; preweighed filter papers; funnel; three beam balance; plastic sandwich bags; notebook; and waterproof laundry pen. The small things were carried in a carpenter's apron.

The procedure was to wade out from shore until an identifiable bedform was found by feeling the bottom with hand or foot. It was then given a sample number and the water depth, velocity and temperature were measured. The bedload sample was taken and finally any notes and a description of the bedform were recorded.

The velocity was measured with a Price Current Meter borrowed from the U. S. Geological Survey office in Bismarck, North Dakota. The support rod of the meter was marked so it could be used to determine the depth of the water.

Water samples were taken with a device (DH48) borrowed from the U. S. Geological Survey office in Grand Forks. The water sample was weighed and the suspended load filtered out on filter papers of

known weight. When the dried suspended load was weighed a parts-per-million-by weight suspended-load concentration was calculated by the formula: $\text{sediment wt.} \times 10^6 / \text{total wt.}$

The bedload sample was taken by scooping a hand-full of material from the bottom. Then it was dropped into a plastic sandwich bag and sealed. A slip of paper with the sample number written on it was then placed with the bag full of sediment into another plastic bag. The samples were carried in a cloth sack hung from the belt. Care was taken not to dig too deep and to grasp the sample very tightly while bringing it to the surface. Lack of attention to these details would make the sample worthless because of contamination or winnowing. Since it requires a minimum of equipment this method is very convenient. I don't know of a mechanical device that does a better job.

Laboratory Methods

The bedload samples were later dried and sieved to remove silt and clay. The sand and total silt-clay portions were weighed and used to calculate the percentage of silt and clay in the total sample. The sand portion was then run through a settling tube identical to one described by Felix (1969) except that the release mechanism is different. The device used was made of slats that could be rotated about their long axis. When the slats were horizontal they held sediment but when they were rotated 45° the sediment slid off to settle through the tube. The tube contained distilled water at a temperature of 22°C .

A computer program written by me and used to calculate Froude and Reynolds numbers is given in Appendix I.

RESULTS AND INTERPRETATION

General

The data, Froude numbers, and Reynolds numbers are given in Appendix II and plotted on Figures 2, 3, and 4.

Velocity: Depth

A simple graph with velocity on one axis and depth on the other is shown in Figure 2. The different bedforms are distinguished by symbols as indicated in the legend.

Froude number.--The solid diagonal lines connect equal Froude numbers. The Froude numbers are unusually small because the velocity was measured near the bed. Mean velocity is usually used in this calculation. For a given velocity near the bed, which should be most significant, the mean velocity increases with the depth of the stream (Colby, 1964, pA7). The amount this affects Froude number is unknown but must be considerable because the dune field in Figure 2 extends down to about 0.15 while Simon, Richardson, Albertson (1961, pA59) found them ranging only down to about 0.30.

Two accepted formulas exist for the Froude number.

$$F = V^2/GD$$

(Allen, 1970, p.21)

$$F = V/\sqrt{GD}$$

(Simons, 1963, p.286)

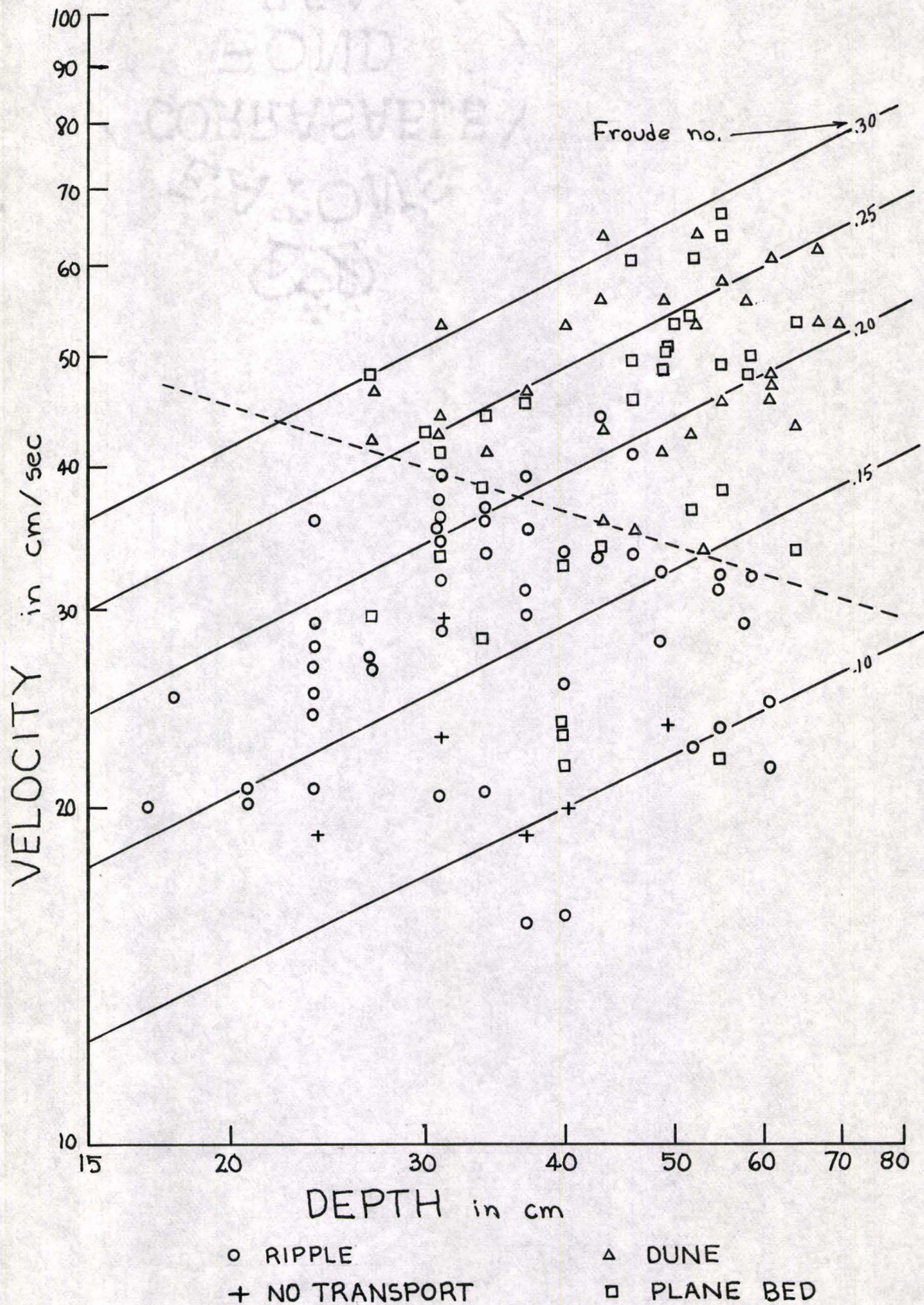
When the velocity and depth have values such that the Froude number is one they are equal: with $V = 3\text{ft/sec}$, $D = 9/32.2\text{ft}$.

$$F = V^2/GD = 1.0$$

$$F = V/\sqrt{GD} = 1.0$$

But if the Froude number is not one they are not equal: with $V = 2\text{ft/sec}$, $D = 9/32.2\text{ft}$

FIG. 2.--Graph of Current Velocity versus Depth.



$$F = V^2/GD = 0.444...$$

$$F = V/\sqrt{GD} = 0.666...$$

with $V = 4\text{ft/sec}$, $D = 9/32.2\text{ft}$

$$F = V^2/GD = 1.777...$$

$$F = V/\sqrt{GD} = 1.333$$

If the Froude number is less than one the value for V^2/GD is less than the value for V/\sqrt{GD} . If the Froude number is greater than one the value for V^2/GD is greater than the value for V/\sqrt{GD} . Changing the depth had an effect opposite to changing the velocity. Below are some examples where the depth changes.

$V = 3\text{ft/sec}$, $D = 8/32.2\text{ft}$

$$F = V^2/GD = 1.125$$

$$F = V/\sqrt{GD} = 1.08$$

$V = 3\text{ft/sec}$, $D = 10/32.2\text{ft}$

$$F = V^2/GD = 0.90$$

$$F = V/\sqrt{GD} = 0.97$$

Both values were calculated but only V/\sqrt{GD} was plotted on the graphs because the values were considerably larger and easier to use.

(Appendix II)

Dune-ripple relationship.---The dashed line on Figure 2 is an inferred boundary between a dune field and a ripple field. Simons, Richardson, Albertson (1961, p. 59) have a similar diagram plotted with some flume data. In that diagram the fields of the bedforms are roughly bounded by lines connecting equal Froude numbers. In Figure 2 the inferred boundary runs at a large angle to the Froude number lines. Their data was limited to depths of 30 cm (about 1 ft) or less, data for Figure 2 is poor at those shallow depths and good for depths up to 70 cm. The boundary in Figure 2 dips steeply to the right indicating that at greater depths the dune bed configuration can form at lower velocities. If there were more data at shallow depths the boundary between ripples

and dunes would probably drop to the left like in Simons' (1961) Figure 22. When the depths became too shallow for ripples or dunes to form the transition to the upper flow regime would be reached.

Other bedforms.--Plane bed data plotted irregularly throughout Figure 2. It seems obvious that more complicated methods will be needed to determine their relationships. The samples taken where there was no transport plot low in the ripple field.

Comments.--Despite the fact that it ignores both water viscosity and grain size of the bedload this simple graph did separate the ripple and dune fields.

Reynolds no.: Froude no.

The dimensionless Reynolds number takes into consideration the viscosity of the water. A graph by Simons, Richardson and Haushild (1963, p.G-17, Fig. 6) relating kinetic viscosity to water temperature and suspended load was used to determine the viscosity. The Reynolds number is calculated by the formula $Re = \text{Velocity} \times \text{Depth} / \text{Kinematic viscosity}$.

Figure 3 is a plot of Reynolds number against Froude number. The results are quite similar to those of Figure 2. Plane bed and no transport were omitted so the relationship between ripples and dunes would be clearer. The separation is more distinct in this graph and the grouping is tighter. The consideration of viscosity seems to have improved the accuracy somewhat.

Reynolds no.: Median Grain Size of Sand

One more factor that should be considered is the size of the material transported as bedload. When the Reynolds number is plotted against median grain size of the sand fraction of the bedload the

FIG. 3.--Graph of Reynolds number versus Froude number.

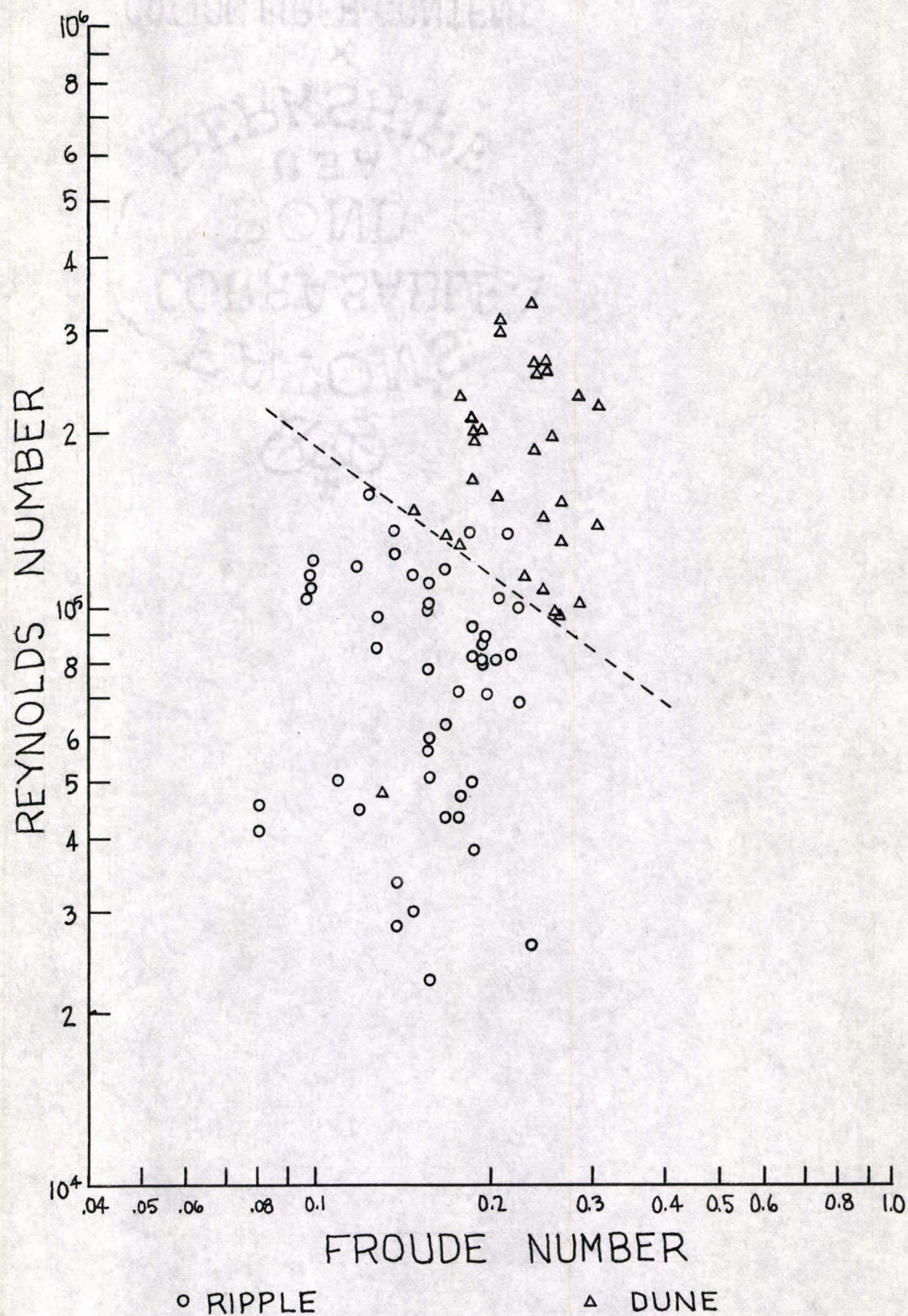
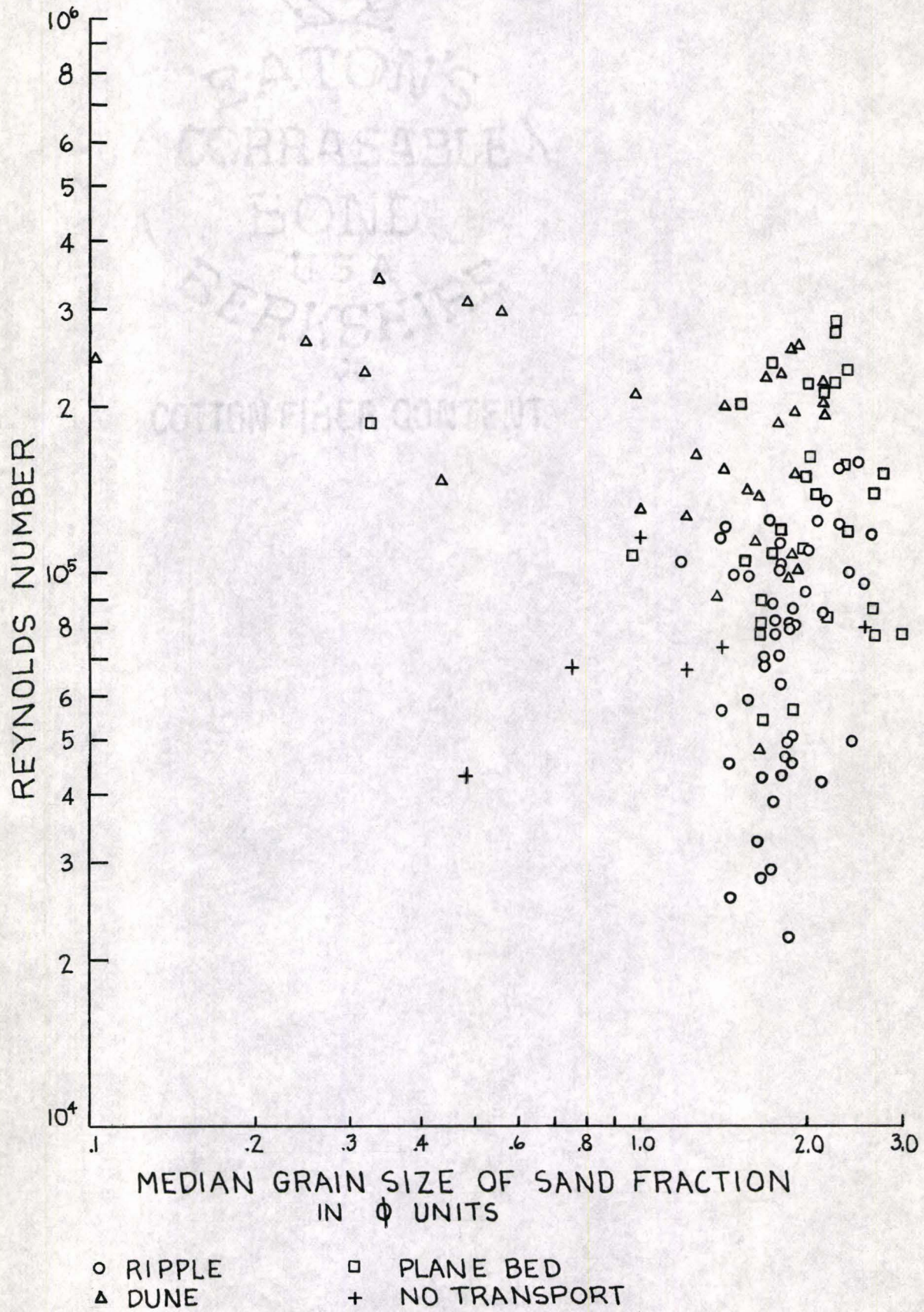


FIG. 4.--Graph of Reynolds number versus Median Grain Diameter of Sand.



factors of current velocity, depth, water viscosity, and grain size of the bedload are taken into consideration. Figure 4 is the result of this plot. Simons and Richardson's (1963, p. 299) Figure 4 does show some similarities in the positions of ripple and dune fields if equal grain sizes on the two graphs are lined up, but it is not a good match.

On Figure 4 the ripple field is terminated on the left by the 1.0 phi grain size. This grain size is thought to be about the maximum size that ripples can form in (Allen, 1970, p. 79).

There is some concentration of plane bed in the fine grain sizes. These samples generally have a higher percentage of silt and clay that may have some effect on erodability and certainly on the cohesion of the grains.

DISCUSSION

A simple plot of velocity against depth worked well to separate ripples from dunes but left plane bed scattered. The plane bed in the dune field may have been confused with tops of bars. The mixing of plane bed and ripples in the graph is interesting considering the number of times ripple crossbeds and plane beds are found mixed in rocks.

Perhaps more complicated plots that consider bed slope and fall velocity are needed to isolate plane bed. Future studies of this type should certainly measure slope. The use of a viscosometer would also be a great improvement over the rather uncertain method of measuring temperature and suspended load to find apparent viscosity from graphs. Colby and Scott (1965) do not have much confidence in Simons' (1963, p. C17) graph that shows the effect of "bentonite" and temperature on apparent kinematic viscosity.

Field studies of this type could be better handled by two people since measuring slope requires the use of a level and rod.

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Effects of Fine Sediment on Flow Phenomena", 47p., Geological
Water-Supply Paper 1498-G.

APPENDIX I

Computer Program used to Calculate

Reynolds and Froude numbers

C THIS PROGRAM WILL COMPUTE FROUDE AND REYNOLDS NUMBERS AND IS SET UP
C TO USE DATA IN THE METRIC SYSTEM**TEMPERATURE IS IN CENTIGRADE

G=980.0

WRITE(3,60)

60 FORMAT(' ',' JSNO BFORM SMGS F AF IR IRT')

1 READ(1,10)JSNO,BF,RM,BPSC,SMGS,TEMP,SUSLD,DEPTH,VEL,WKVISC

10 FORMAT(I6,2A4,F4.1,1X,F4.2,1X,F4.1,2X,F7.1,2X,F4.1,2X,F4.1,1X,F4.
&2)

C JSNO IS THE SAMPLE NUMBER;BF,RM IS THE BEDFORM;BPSC IS THE PERCENT
C SILT-CLAY IN THE BED;SMGS IS THE MEDIAN GRAIN SIZE OF SAND IN BED;
C TEMP IS THE WATER TEMPERATURE;SUSLD IS THE SUSPENDED LOAD IN PARTS
C PER MILLION BY WEIGHT;DEPTH IS IN CM;VEL IS VELOCITY IN CM/SEC;
C WKVISC IS KINEMATIC VISCOSITY IN ENGLISH UNITS X 100,000
IF(JSNO)3,3,2

C THE FROUDE NUMBER CALLED F IS BEST FOR FROUDE NUMBERS LESS THAN ONE
C $F = \text{VELOCITY DIVIDED BY THE SQUARE ROOT OF THE QUANTITY (ACCELERAT}$
C $\text{ION OF GRAVITY TIMES THE DEPTH)}$

2 F=VEL/SQRT(G*DEPTH)

C THE FROUDE NUMBER AF IS BEST FOR THOSE GREATER THAN ONE
C $AF = \text{VELOCITY SQUARED DIVIDED BY THE QUANTITY(ACCELARATION OF GRAV}$
C ITY TIMES DEPTH)

AF=VEL*VEL/(G*DEPTH)

C HERE VISCOSITY IS CHANGED TO METRIC UNITS

WKVISC=WKVISC*0.0093

C REYNOLDS NUMBER = VELOCITY TIMES DEPTH DIVIDED BY THE KINEMATIC
C VISCOSITY

C THE REYNOLDS NUMBER IR USES A VALUE FOR KINEMATIC VISCOSITY FROM
C THE DATA DECK**THIS VALUE CAN BE INTERPRETED FROM A GRAPH BY SIMONS
C (1963) USGS WTR SUPPLY PAPER 1498-G, P47
IR=VEL*DEPTH/WKVISC
C THE REYNOLDS NUMBER IRT ONLY CONSIDERS TEMPERATURE TO DETERMINE
C THE KINEMATIC VISCOSITY
IF(TEMP.GE.10.0.AND.TEMP.LE.15.6)GO TO 4
IF(TEMP.GE.15.7.AND.TEMP.LE.21.1)GO TO 5
IF(TEMP.GE.21.2.AND.TEMP.LE.26.7)GO TO 6
4 TVISC=1.3*0.0093
GO TO 7
5 TVISC=1.1*0.0093
GO TO 7
6 TVISC=1.0*0.0093
7 IRT=VEL*DEPTH/TVISC
WRITE(3,50)JSNO,BF,RM,SMGS,F,AF,IR,IRT
50 FORMAT(' ',I6,2A4,F4.2,1X,F4.2,1X,F4.2,1X,I10,1X,I10)
GO TO 1
3 STOP
END

APPENDIX II

Data collected and Reynolds numbers
and Froude numbers calculated

BASIC DATA

SMPL. NO.	DEPTH cm	VELOCITY cm/sec	TEMP °C	SUSPENDED LOAD (PPM)	SILT-CLAY %	BED FORM
270513	43	33.2	21	13200	0	ripple
270516	31	20.5	21	13200	0	ripple
290514	37	29.7	18	8220	0	ripple
290515	34	33.8	18	8220	0	ripple
290516	34	36.9	18	8220	0	ripple
290517	27	26.5	18	8220	0	ripple
290518	24	29.2	18	8220	0	ripple
290519	24	25.4	18	8220	0	ripple
010605	24	20.9	12.5	2125	0	ripple
010606	31	28.7	12.5	2125	0	ripple
010607	24	26.9	12.5	2125	0	ripple
010608	21	20.9	12.5	2125	0	ripple
010609	21	20.1	13	2125	0	ripple
010610	17	20.1	13	2125	0	ripple
010613	31	34.4	13.5	2125	0	ripple
010615	24	27.8	15	2125	0	ripple
010618	31	37.5	15	2125	0	ripple
010619	37	39.3	15	2125	0	ripple
010624	40	16.1	15.5	2125	0	ripple
010625	37	15.8	15.5	2125	0	ripple
010632	49	32.6	16	2125	0	ripple
020616	46	33.8	18	4230	0	ripple
020617	46	41.1	18	4230	0	ripple
020618	43	44.5	18	4230	0	ripple
020620	37	35.4	18	4230	0	ripple
020621	34	36.0	18	4230	0	ripple
020622	55	31.4	18.5	4230	0	ripple
020623	31	35.4	18.5	4230	0	ripple
020624	31	32.0	18.5	4230	0	ripple
020625	31	36.0	18.5	4230	0	ripple
020626	31	35.4	18.5	4230	0	ripple
080602	61	23.7	16.5	4385	16.9	ripple
080604	58	29.4	16.5	4385	62.0	ripple
080607	49	28.3	17	4385	4.9	ripple
080608	55	32.3	17	4385	2.1	ripple
090602	34	20.9	18	5423	13.5	ripple
110601	59	32.3	20	2886	2.1	ripple
110632	61	24.9	22	2886	3.2	ripple
110633	40	25.9	22	2886	8.7	ripple
280603	24	36.0	20	2865	0	ripple
290602	31	39.3	21.5	3000	0	ripple
300601	12	25.5	23	3403	0	ripple
300602	18	25.2	23	3403	0	ripple
300603	27	27.2	23	3403	0	ripple
300605	40	33.8	23	3403	0	ripple
010705	37	31.4	21	1117	0	ripple
010709	52	22.7	25	817	0	ripple
010711	55	23.7	26	817	0	ripple
040707	24	24.3	24	352	0	ripple

BASIC DATA

SMPL. NO.	MEDIAN G.S.- ϕ	VISC $\nu \times 10^5$	FROUDE V/\sqrt{GD}	FROUDE V^2/GD	REYNOLDS TEMP.&SL	REYNOLDS TEMP
270513	1.81	1.50	0.16	0.03	102258	139550
270516	1.47	1.50	0.12	0.01	45483	62121
290514	1.77	1.50	0.16	0.02	78774	107419
290515	1.78	1.50	0.19	0.03	82366	112366
290516	1.77	1.50	0.20	0.04	89892	122639
290517	1.93	1.50	0.16	0.03	51290	69941
290518	1.92	1.50	0.19	0.04	50215	68504
290519	1.83	1.50	0.17	0.03	43656	59589
010605	1.66	1.60	0.14	0.02	33656	41488
010606	1.63	1.60	0.16	0.03	59785	73589
010607	1.69	1.60	0.18	0.03	43333	53399
010608	1.79	1.60	0.15	0.02	29462	36302
010609	1.68	1.60	0.14	0.02	28280	34913
010610	1.88	1.60	0.16	0.02	22903	28263
010613	1.71	1.60	0.20	0.04	71613	88205
010615	1.88	1.50	0.18	0.03	47742	55186
010618	2.19	1.50	0.22	0.05	83333	96153
010619	1.82	1.50	0.21	0.04	104194	120273
010624	1.93	1.50	0.08	0.01	46129	53267
010625	2.15	1.50	0.08	0.01	41828	48354
010632	1.82	1.50	0.15	0.02	114409	156148
020616	2.03	1.50	0.16	0.03	111398	151984
020617	2.13	1.50	0.19	0.04	135484	184809
020618	2.06	1.50	0.22	0.05	137097	187048
020620	2.03	1.50	0.19	0.03	93870	128035
020621	1.92	1.50	0.20	0.04	87742	119648
020622	1.75	1.47	0.14	0.02	126237	168817
020623	1.91	1.47	0.20	0.04	80215	107272
020624	1.81	1.47	0.18	0.03	72473	96969
020625	1.93	1.47	0.21	0.04	81613	109091
020626	1.90	1.47	0.20	0.04	80215	107272
080602	2.44	1.53	0.10	0.01	101505	141319
080604	2.65	1.53	0.12	0.02	119785	166686
080607	2.61	1.53	0.13	0.02	97419	135552
080608	2.34	1.53	0.14	0.02	124839	173656
090602	2.48	1.50	0.11	0.01	50860	69462
110601	2.34	1.30	0.13	0.02	157527	186285
110632	2.11	1.30	0.10	0.01	125591	163322
110633	2.21	1.30	0.13	0.02	85591	111397
280603	1.97	1.35	0.23	0.06	68817	84457
290602	1.51	1.30	0.23	0.06	100753	130999
300601	1.47	1.25	0.24	0.06	26237	32903
300602	1.78	1.25	0.19	0.04	38925	48774
300603	1.81	1.25	0.17	0.03	63118	78967
010705	1.60	1.25	0.16	0.03	99892	113568
010709	1.21	1.20	0.10	0.01	105699	126924
010711	1.44	1.15	0.10	0.01	121828	140161
040707	1.42	1.10	0.16	0.03	56989	62709
300605	1.42	1.25	0.17	0.03	116236	145376

BASIC DATA

SMPL. NO.	DEPTH cm	VELOCITY cm/sec	TEMP °C	SUSPENDED LOAD (PPM)	SILT-CLAY %	BED FORM
270510	31	23.2	19	13200	0	dune
290511	61	46.0	18	10480	0	dune
290513	40	53.3	18	10480	0	dune
010602	52	53.3	12.5	1913	0	dune
010622	31	44.5	15.5	1913	0	dune
010626	49	56.1	15.5	1913	0	dune
020604	52	64.6	15	4230	0	dune
020605	61	61.3	15	4230	0	dune
020611	61	47.2	15	4230	0	dune
100608	61	58.5	18.5	3443	0	dune
100618	70	53.9	20	3443	0	dune
100620	67	53.9	20	3443	0	dune
100623	64	43.9	20	3443	0	dune
110616	53	33.8	21	2886	0	dune
130608	58	56.1	21	5089	0	dune
130627	55	46.0	23	5089	0	dune
130637	43	64.0	24	5089	0	dune
130638	55	58.5	24	5089	0	dune
130641	67	62.5	24	5089	0	dune
280605	31	43.0	20	2865	0	dune
280606	27	42.1	20	2865	0	dune
280607	27	46.9	20	2865	0	dune
290603	34	41.1	21.5	3000	0	dune
290604	31	53.9	21.5	3000	0	dune
290605	46	35.1	21	3000	0	dune
290606	37	46.9	21	3000	0	dune
290607	43	43.9	21	3000	0	dune
290608	43	36.0	21	3000	0	dune
290611	49	41.1	21.5	3000	0	dune
040721	52	43.0	25	352	0	dune
050704	43	56.1	25	662	0	dune
290510	64	33.8	18	10480	0	plane
290521	52	54.6	18	8220	0	plane
290523	34	44.5	18	8220	0	plane
010604	52	61.3	12	2125	0	plane
010620	37	46.0	15	2125	0	plane
010631	27	29.7	16	1913	0	plane
020615	46	46.0	18	4230	0	plane
020619	46	50.0	18	4230	0	plane
060601	40	32.9	17	19469	39.9	plane
080601	55	22.2	16.5	4385	55.6	plane
080605	55	38.4	16.5	4385	53.4	plane
100621	58	50.6	20	3443	0	plane
110603	52	36.9	20	2886	4.4	plane
110604	34	28.3	20	2886	5.4	plane
120622	58	48.2	23	3707	1.1	plane
130624	55	49.4	23	5089	0	plane
130631	49	49.4	23	5089	0	plane
130632	49	61.3	23	5089	0	plane

BASIC DATA

SMPL. NO.	MEDIAN G.S.- ϕ	VISC $\nu \times 10^5$	FROUDE V/\sqrt{GD}	FROUDE V^2/GD	REYNOLDS TEMP.&SL	REYNOLDS TEMP
270510	1.66	1.60	0.13	0.02	48279	70303
290511	1.44	1.50	0.19	0.04	201075	274291
290513	1.93	1.50	0.27	0.07	152796	208406
010602	1.78	1.60	0.24	0.06	186237	229247
010622	1.86	1.50	0.26	0.07	98817	114102
010626	2.17	1.50	0.26	0.07	196989	227369
020604	1.82	1.57	0.29	0.08	230000	277849
020605	1.89	1.57	0.25	0.06	256021	309288
020611	1.93	1.57	0.19	0.04	197097	238147
100608	0.25	1.45	0.24	0.06	264632	348827
100618	0.49	1.30	0.21	0.04	312043	368817
100620	0.56	1.30	0.21	0.04	298602	353011
100623	0.31	1.30	0.18	0.03	232366	274643
110616	0.44	1.30	0.15	0.02	148172	175112
130608	0.00	1.40	0.24	0.06	249892	318064
130627	2.33	1.35	0.20	0.04	201505	272043
130637	2.32	1.33	0.31	0.10	222473	295914
130638	1.95	1.33	0.25	0.06	260108	345967
130641	0.34	1.33	0.24	0.06	338495	450267
280605	1.92	1.33	0.25	0.06	107742	130303
280606	1.40	1.33	0.26	0.07	91828	111114
280607	1.95	1.33	0.29	0.08	102366	123783
290603	1.64	1.30	0.23	0.05	115484	150258
290604	1.65	1.30	0.31	0.10	138172	179666
290605	1.01	1.30	0.17	0.03	133548	157830
290606	1.57	1.30	0.25	0.06	143441	169628
290607	1.44	1.30	0.21	0.05	156129	184526
290608	1.21	1.30	0.18	0.03	127957	151319
290611	1.28	1.30	0.19	0.04	166559	216548
040721	0.98	1.13	0.19	0.04	212688	280430
050704	1.71	1.13	0.27	0.07	229462	259387
290510	1.70	1.50	0.13	0.02	155054	211456
290521	1.54	1.50	0.24	0.06	203440	277536
290523	1.77	1.50	0.24	0.06	108387	147898
010604	2.03	1.60	0.27	0.07	222366	273796
010620	1.83	1.50	0.24	0.06	121935	140777
010631	1.92	1.50	0.18	0.03	57419	78387
020615	2.03	1.50	0.22	0.05	151613	206842
020619	2.06	1.50	0.24	0.06	164839	224829
060601	2.70	1.80	0.17	0.03	78602	128641
080601	2.69	1.50	0.10	0.01	87419	119354
080605	2.81	1.50	0.17	0.03	151290	206451
100621	1.75	1.30	0.21	0.05	242688	286881
110603	2.33	1.30	0.16	0.03	158710	187566
110604	1.71	1.30	0.16	0.02	79570	94056
120622	2.11	1.25	0.20	0.04	240430	300602
130624	2.23	1.37	0.21	0.05	213226	292150
130631	0.33	1.37	0.23	0.05	189892	260279
130632	2.42	1.37	0.28	0.08	235699	322978

BASIC DATA

SMPL. NO.	DEPTH cm	VELOCITY cm/sec	TEMP °C	SUSPENDED LOAD (PPM)	SILT-CLAY %	BED FORM
130634	55	64.0	23	5089	0	plane
130635	55	67.4	23	5089	0.9	plane
130636	46	61.3	23	5089	0	plane
280608	31	43.0	20	2865	0	plane
280610	27	48.2	20	2865	0	plane
290609	34	38.4	21	3000	0.5	plane
300604	31	33.8	23	3403	0	plane
040701	40	21.8	24	445	0	plane
050603	52	61.3	16	36083	63.0	plane
050604	50	53.9	16	36083	32.7	plane
050605	64	53.9	17.5	36083	26.5	plane
050606	43	33.8	17.5	25372	93.4	?plane
050601	21	7.7	16	25372	61.7	notran
070605	49	23.7	17	9580	24.7	notran
010704	31	29.5	21	1117	0	notran
040711	24	19.0	25	352	4.3	notran
040712	37	19.0	25	352	1.4	notran
040713	40	20.1	25	352	0	notran
040714	34	35.4	25	352	0	?notran

SMPL. NO.	MEDIAN G.S.- ϕ	VISC $\nu \times 10^5$	FROUDE V/\sqrt{GD}	FROUDE V^2/GD	REYNOLDS TEMP.&SL	REYNOLDS TEMP
130634	2.29	1.37	0.28	0.08	276237	378494
130635	2.29	1.37	0.29	0.08	290860	398602
130636	2.25	1.37	0.29	0.08	221290	303204
280608	1.90	1.33	0.25	0.06	107742	130303
280610	1.57	1.33	0.30	0.09	105161	127214
290609	0.98	1.30	0.21	0.04	107957	127624
300604	1.70	1.25	0.19	0.04	90108	112666
040701	1.70	1.15	0.11	0.01	81505	93763
050603	2.69	2.40	0.27	0.07	142796	311593
050604	2.43	2.40	0.24	0.06	120645	263441
050605	2.53	2.30	0.22	0.05	161183	337204
050606	3.02	2.00	0.16	0.03	78065	142072
050601	2.69	2.05	0.05	0.0-	8387	15806
070605	2.55	1.55	0.11	0.01	80538	113519
010704	1.21	1.40	0.17	0.03	70215	89394
040711	0.48	1.10	0.12	0.02	44516	49032
040712	0.75	1.10	0.10	0.01	68710	75591
040713	1.44	1.10	0.10	0.01	78495	86451
040714	1.06	1.10	0.19	0.04	117634	129419